Integrated Aquatic Community and Water Quality Monitoring of Mountain Ponds and Lakes in the Klamath Network – Annual Report

2008 results from Pilot Project in Lassen Volcanic National Park

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Preface

This report is meant as a stand-alone progress report on the Lakes monitoring of the Klamath Inventory and Monitoring Network. The intended audience is park managers, park specialists, interested regional scientists, and the general public. Although many details concerning the protocol are best obtained from reading the entire protocol, it is our aim that this report be understandable without further reading. The format and level of detail chosen to achieve this is similar to a scientific publication, albeit with the goal of reaching a broad audience. The topics covered by these reports, written every three years at the completion of a sampling period for the lakes of the network are: (1) lists of lakes sampled, with basic parameters summarized; (2) biodiversity information (zooplankton; invertebrates; fish; amphibians) of each lake; (3) updates to accumulated biodiversity incorporating multiple sample periods; (4) status estimates where applicable; and (5) interesting findings of special significance to the audience.

Abstract

In 2008, the Klamath Inventory and Monitoring Network, with assistance from the USGS FRESC field station, initiated a pilot project of lake and pond monitoring protocols in ecosystems of Lassen Volcanic National Park. The purpose of the pilot project was to field test draft standard operating protocol methods, for evaluation of suitability, feasibility, and to derive estimates of variation for power analyses. This report serves as a model for the format and content of Annual Reports that will be produced from the final implementation of the protocol.

A total of 25 sites were visited in 2008 from 10 September to 16 October, including 4 sites that were deemed unsuitable for sampling. The methods from the draft protocol were largely successful, with few problems encountered. Adjustments made to the protocol were: (1) increasing the amount of water collected for water samples; and (2) refined the filter choice for Chlorophyll *a* analysis.

Based on various Trophic State Indices, the lakes of Lassen Volcanic National Park are mostly oligotrophic, although there are also many mesotrophic lakes as well. A minority of lakes are eutrophic.

A total of 16,415 zooplankton were identified from Lassen Volcanic National Park, from 68 total taxa. Species richness was estimated theortically at 184 total taxa. A total of 12,507 macroinvertebrates were identified, from 104 total taxa. The species richness was estimated at 140 total taxa.

Fish were only identified at two lakes (9.5% of the lakes sampled). Summit Lake contained Brook Trout (*Salvelinus fontinalis*) and Reflection Lake contained Golden Shiner (*Notemigonus crysoleucas*).

An outbreak of ranavirus inflicting Long-toed salamanders (*Ambystoma macrodactylum*) was observed at Cliff Lake. More than 30 individuals in the metamorph lifestage were seen either moribund or dead. Diagnosis of ranavirus was confirmed by the USGS National Wildlife Health Center.

Acknowledgements

Introduction

The Klamath Network vital sign selection process resulted in the identification of two aquatic resource vital signs for monitoring: Aquatic Communities and Water Quality (Sarr et al. 2007). Prioritization of these vital signs was driven by potential natural and anthropogenic stressors on water resources (including physical, chemical, and biological characteristics) of freshwater habitats and resources. Identified stressors of aquatic resources included (1) climate change, (2) atmospheric deposition of pollutants and nutrients, (3) introduced and invasive species, (4) recreational visitor use, and (5) land use, including park maintenance activities.

The Klamath Network is located in southern Oregon and Northern California, and includes the National Park Service Units of: Crater Lake National Park (CRLA), Lassen Volcanic National Park (LAVO), Lava Beds National Monument (LABE), Oregon Caves National Monument (ORCA), Redwood National and State Parks (RNSP), and Whiskeytown National Recreation Area (WHIS). Lassen Volcanic National Park and Crater Lake National Park are the only parks of the network with substantial natural, lentic ecosystems.

During the scoping process and Vital Sign determination process (detailed in Sarr et al. 2007), and emphasis was put on two aspects of the water quality monitoring: (1) a probabilistic sample, allowing determination of park wide status and trends; and (2) an integrated ecosystem approach to monitoring. To accomplish the first aspect, we implemented a spatially-balanced probability sampling throughout the park boundaries, called Generalized Random Tessellation Stratified - (GRTS). This procedure is random, but by spatially balancing the spread of sites, it ensures that all areas of the park are represented in the sample. To accomplish the second aspect, we are sampling as much of the components of the ecosystem as possible: physical habitat, water chemistry, phytoplankton biomass, zooplankton assemblage, macroinvertebrates, amphibians, and fish. By sampling all of these (balanced against what is logistically and financially possible), an integrated approach to monitoring ecosystem change can be had.

This annual report details the results of the monitoring of 25 lentic (lakes and ponds – hereafter, just "lakes") ecosystems of Lassen Volcanic National Park sampled as a part of the pilot project developing the monitoring protocol. The full objectives of the lakes protocol are presented in the protocol narrative (Dinger et al., in development – this document). This annual report focus on portions of the objectives, mainly the characterization of the habitat, water quality, and biotic communities in a probabilistic sample of mountain lakes and ponds and provides estimates of status.

Methods

Study site

This project was carried out in Lassen Volcanic National Park, northern California (Figure 1). Lassen Volcanic National park covers 106,000 acres of volcanic legacy mountains, at medium to high elevations 1524 m (5000 ft) to a high of 3,187 m (10,457 ft – Lassen Peak). It is still an active volcanic area, and remnants of geological activity are present in the fumaroles, hot springs, and mud pots. Geographically, it is located in between the Sierra Nevada Mountains, to the south, and the Cascade Mountains, to the north.

Lassen Volcanic National Park has the most numerous lakes resources of the six parks in the network. These lakes vary from large, deep lakes (e.g., Lake Helen at 32.5 m deep; 26 acres) to small, shallow, ephemeral ponds. A total of 239 waterbodies are recorded in the National Hydrography Dataset (with 203 within the Lakes Protocol sampling frame).

In this report, we visited a total of 25 lakes, with 21 being sampleable (Table 1) and 4 being unsampeable (Table 2). Of the 21 sampled, 11 were "survey" lakes, 9 were "index" lakes, and 1 was a judgment lake. Lakes that were not sampled were either completely dry (once), too shallow to sample without stirring up sediments ; therefore contaminating samples(twice), or were geothermic sites that would pose hazard to crew and gear (once).

Water chemistry and profile

Using a small inflatable raft to investigate likely deep spots, the deepest portion of the lake was determined using a hand-held sonar. At the deepest portion, water samples were taken using a pre-conditioned Beta Van Dorn horizontal water sampler. If the lake was deeper than 2 meters, a sample was taken 0.5 meters below the water surface (representing the epilimnion) and another sample taken at 0.5 m above the lake bottom (representing the hypolimnion). If the lake was shallower than 2 meters, a single sample in the middle of the water column was taken.

On shore, using a 60 mL syringe and filter holder, each water was filtered through a 0.45 µm nylon membrane filter into an amber, high-density-poly-ethylene, acid washed 250 ml bottle. After 250 ml were filtered, the bottle was capped and kept cool until able to freeze (generally <4 hours). These samples were then shipped to the Cooperative Chemical Analytical Laboratory at Oregon State University, Corvallis. These samples were analyzed for: anions (Ca^{2+}, Na^+, K^+, and Mg^{2+}); cations (SO_4^{2-} and Cl^-); and nutrients (total dissolved nitrogen, dissolved inorganic nitrogen, total dissolved phosphorous). Furthermore, acid neutralizing capacity was determined in the field using Hach digital titrator kits.

For dissolved organic carbon, an additional aliquot of 60 ml was filtered through a glass-fiber filter (GF/F) pre-combusted at 500° C for 4 hrs. The sample was filtered into an acid-washed, pre-combusted (475° C for 8 hr) amber glass vial, and all care was taken to minimize the headspace.

Table 1. Locations and specifics of lakes sampled during pilot project. Coordinates are in Universal Transverse Mercator (WGS 1984). Lake circumference ("circum") and area are determined using GPS units, max depth with a handheld sonar, and volume and shoreline development are calculated later with equations (see text for more details).

Site Name	Date (mm/dd/yy)	Panel type	Coordinates Easting	Coordinates Northing	County	Lake circum (m)	Area (m^2)	Max depth (m)	Volume (m^3)	Shoreline development
Cluster Pond 4	9/10/2008	Survey	636039	4488540	Shasta	369.7	7544.0	2.4	295.5	110.7
Summit Lake	9/11/2008	Survey	633596	4483737	Shasta	1069.8	55889.4	2.2	783.7	482.0
Reflection Lake	9/16/2008	Index	621472	4488403	Shasta	950.0	31559.7	4.5	1423.6	288.8
Little Bear Lake	9/17/2008	Survey	634943	4487095	Shasta	433.8	11593.3	2.2	317.8	157.0
Cluster Lake 4	9/17/2008	Survey	636039	4488540	Shasta	758.8	13005.6	0.9	227.4	133.2
Cluster Lake 3	9/18/2008	Index	636073	4488263	Shasta	1405.3	69544.3	4.5	2105.8	523.3
Lake Helen	9/22/2008	Judgment	626277	4480838	Shasta	1221.3	104832.0	32.5	13217.1	846.2
Cliff Lake	9/23/2008	Index	630941	4481819	Shasta	658.5	21935.7	3.4	745.6	241.1
Forest Lake	9/24/2008	Index	622914	4477518	Tehama	505.3	8646.4	3.6	605.8	108.5
Unnamed #36	9/25/2008	Survey	631507	4479744	Shasta	120.6	777.4	0.8	32.1	20.0
Unnamed #27	9/30/2008	Survey	648123	4482263	Lassen	278.6	2904.5	2.1	194.9	49.1
Jakey Pond #6	10/1/2008	Survey	646831	4481744	Lassen	349.6	6763.4	2.7	314.3	102.0
Inspiration Pond 2	10/1/2008	Index	644437	4482174	Lassen	330.4	6033.0	1.6	176.1	93.6
Crystal Lake	10/3/2008	Index	644979	4480116	Lassen	692.9	24568.5	5.7	1315.1	263.3
Unnamed #34	10/3/2008	Survey	645830	4476929	Lassen	200.6	2388.3	1.8	120.2	47.6
Hidden Lake	10/5/2008	Survey	641493	4483550	Shasta	887.3	30694.8	3.2	945.5	290.7
Indian Lake	10/6/2008	Index	641707	4479663	Shasta	1064.8	30111.4	4.2	1489.3	260.3
Indian Pond	10/6/2008	Survey	641827	4479956	Lassen	396.5	8176.5	6.4	845.1	115.8
Bathtub Pond	10/14/2008	Survey	644358	4492273	Lassen	430.4	10233.3	5.6	802.7	139.1
Rainbow Lake	10/15/2008	Index	639982	4485796	Shasta	1353.3	94437.0	8.8	3965.7	724.2
Soap Lake	10/16/2008	Index	637122	4490226	Shasta	586.1	18159.4	0.9	175.7	211.6

Table 2. Locations visited during pilot project, but not sampled and reason for not sampling.

Site Name	Date (mm/dd/yyyy)	Panel Type	Coordinates		County	Reason for not sampling
			Easting	Northing		
Dersch Meadows	9/9/2008	Index	631493	4485771	Shasta	Too shallow (<1 m); wetland, not lake/pond.
Unnamed # 11	9/30/2008	Survey	647365	4481816	Lassen	"Lake" was dry.
Little Willow Lake	10/4/2008	Index	636532	4474625	Plumas	Too shallow (<1 m); wetland, not lake/pond.
Boiling Springs Lake	10/4/2008	Survey	635882	4477345	Plumas	Mud pot; not lake/pond.

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At the deepest portion of each lake, the vertical profiles of the following attributes were determined every 0.5 m: temperature, conductivity, pH, turbidity, dissolved oxygen, and oxidation-reduction potential. Secchi depth using a 20 cm diameter Secchi disk was used to measure water clarity at the deep point of the lake.

Physical characteristics
Area of the wetted perimeter was measured by walking around the lake using a Trimble GPS unit, logging a line area. This allows the use of GIS software applications to determine the actual areal extent of the lake at the time of sampling. During this walkaround, the type of substrate dominating the wetted, near shore (within 2 m of shore) was also documented in the Trimble GPS. For each lake, the total % of substrate type was then calculated using GIS applications (substrate types: bedrock, cobble, gravel, sand, silt, detritus, emergent macrophytes, submergent macrophytes, woody debris).

Using the circumference (i.e., wetted perimeter), the shoreline development was calculated as the ratio of the actual shore line to that of a circumference of a perfect circle of the same surface area, with a higher number indicated greater potential for littoral zones development and complexity (Wetzel 2001).

Assuming the lake bottom has a perfect cone contour; lake area, and max depth were used to calculate an approximate volume (Wetzel 2001).

Aquatic communities
The pelagic algal community was quantified as chlorophyll *a* biomass (µg/L) (described as above from water chemistry) from the same sampling locations as the water chemistry. Although desirable, phytoplankton species assemblage and identifications are too costly to allow for widespread sampling

Zooplankton was collected from the deepest portion of the lake, using Wisconsin style plankton nets (12.7 cm opening; 63 µm mesh). Six replicate tows were taken; in lake greater than 2 m deep, the tows were horizontal (5 m long max per tow); in shallow lakes less than 2 m deep, tows were horizontal. After each tow, the zooplankton was transferred to a collection vial; all replicate tows were then composited into a single composite sample, and preserved in 70% ethanol. Species identifications were performed by a contract laboratory and reported as # individuals per m^3.

Aquatic macroinvertebrates were sampled using the "standard sweep" method from the near-shore littoral zone (Knapp et al. 2005). A 0.30 cm wide D-frame net was dragged across the lake substrate for 1 m; and then back across the substrate for a second time. This allowed a semi-quantitative collection of 0.30 m^2 per sweep. Sweeps were located at regular intervals around the lake to systematically collect from all substrate types. If accumulated sample detritus was over 2 L, the samples were field split to accommodate the sample containers, by the floating the debris in a 500 µm sieve, and mechanically splitting the sample in half. This process was repeated if necessary. The total sample density was then converted to individuals per m^2. The sample was preserved in 95% ethanol and shipped to a contract laboratory for species enumeration and

identification. At two sites, a secondary method for collecting macroinvertebrates, qualitative collecting, was used. The purpose of qualitative sampling is merely to collect as many different types of macroinvertebrates in as many different microhabitats as possible, using nets, hands and forceps to collect them. We then compared the taxa list from quantitative sampling to the taxa list from qualitative sampling to assess the effectiveness of quantitative sampling for the purpose of describing biodiversity.

Fish were sampled for catch-per-unit-effort using a single gill net (monofilament: 42 m long; panels of [1] 25mm mesh X 6 m; [2] 35 mm X 12 m; and [3] 50 mm X 24 m length). The net was set out in a straight direction from shoreline to the centroid of the lake. In lakes shallower than 2 m, nets were not deployed over concern for snagging on the lake bottom. In these sites, fish presence/not detected relied on crew observations from shore. The net was left deployed for a minimum of two hours, although longer deployments were possible if other tasks delayed the time of retrieval. Any fish collected were identified to species, measured for standard length, and weighed with a portable scale.

Amphibians were sampled by Visual Encounter Surveys, performed during the walk-around of the wetted perimeter. Location of amphibians, species identifications, and numbers (if possible) were recorded into the Trimble GPS unit as they were encountered during the walk-around. One crew member walked in the water performing intensive searches of substrates, while the other was at the perimeter recording the substrate type and recording the data.

Derived metrics and data analyses

To determine trophic status of lakes, we used the Trophic State Indicators of Carlson (1977). Trophic status indicators (TSIs) serve as an index of lake enrichment or trophic state. A high index indicates a eutrophic lake, while a low index indicates an oligotrophic lake. It can be calculated using the following four measures: 1) Secchi depth, 2) Total phosphorous, 3) Total nitrogen, and 4) Chlorophyll *a*.

Where SD = Secchi depth in meters.

Where TP = Total phosphorous in µg/L.

Where TN = Total nitrogen in µg/L.

Where Chl a = Chlorophyll *a* in µg/L.

For macroinvertebrates and zooplankton, we calculated the Shannon Index (H'), a commonly used index of biodiversity that incorporates relative abundance with species richness, using the following equation:

Where p_i = the proportion of the ith species (e.g. abundance of species i divided by the total abundance of the sample).

We used the Hilsenhoff Biotic Index, a weighted average of tolerance values (from $0 - 10$) to examine the macroinvertebrate assemblage:

Where   = the number of individuals for taxa ,   = the assigned tolerance value of taxa , and   = the total number of individuals for a sample. This is a univariate measure collasped from a multivariate measures of species tolerances, where high numbers indicate tolerant communities, and low values indicate intolerant communities.

For fish collections, we calculated fish condition index, Kn with the following equation:

Fish condition index is a species specific evaluation of fish health based on a simple ratio of weight to length; with the premise that a larger fish should be heavier. It is used to assess change of population health over time, or to compare populations of the same species; but should not be used to compare species.

Of these derived indices, we focus our reporting on the park wide averages and variances (standard error and ranges) for these values, along with species lists.

Although the focus of this report is on the presentation of the results of the pilot project, preliminary data analysis entailed the use of species accumulation curves and species richness estimators to evaluate our sampling efficiency. We used Primer-E (Clarke and Warwick, 2001) to estimate the total species richness using the Chao 2 estimator, which uses the number of singletons (species only found in one site) and doubletons (species only found in two sites) to extrapolate to the overall potential park biodiversity. This was done on zooplankton and macroinvertebrates.

The RELATE function of Primer-E was also used to determine the strength of correlation between the following site by parameter matrices: macroinvertebrates; zooplankton; environmental parameters; and water chemistry. The *a priori* hypotheses are that Environmental parameters (e.g., shoreline development, substrate composition, etc.) should have high correlations with macroinvertebrates, whereas the zooplankton should correlate with water chemistry. The RELATE function is based on the Spearman correlation coefficient (r), and is tested for significance using random permutations of the data matrices (the observed value

should be higher than 5% of the randomized values). The higher the r, the higher the correlation of the two datasets is; indicating a connection between the invertebrate assemblage and environmental parameters, for instance. Prior to testing, biotic matrices were standardized to species maximum and square root transformed; environmental and water chemistry matrices were normalized.

Results

A total of 25 lakes were visited from 9 September to 16 October 2008. Of these, four were deemed to not fit the sampling requirements of the protocol. Reasons for rejecting them for sampling were largely that they were shallow wetlands, already dry, or extreme habitats that were not safe for the crew or equipment. Of the 21 lakes samplable, 16 were over 2 meters deep, so that dual water samples (deep and shallow) were collected.

Physical measurements and profiles

Physical substrates of the lakes were dominated by sand (average of 21.9% of all lake substrates) and silt (20.4%). Other categories and average percents were: woody debris (17.3%); fine detritus (13.3%); cobble (9.8%); boulder (7.2%); gravel (3.6%); submergent macrophytes (3.4%) and emergent macrophytes (2.6%).

Profile measurements at each lake, useful for understanding the thermal mixing characteristics of each lake, were averaged for the entire water column for summary purposes. Averages and measures of dispersion were then calculated across the lakes (Table 3). Temperature was relatively cold (at 12.8 °C); but no thermoclines were apparent except at Lake Helen, where there was a thermocline from 13 to 11 °C at a depth of 20 meters (with a max depth of 32.5 m). No other strong association of conductivity, dissolved oxygen, pH or Oxidative/Reduction potential or turbidity were seen with depth.

Table 3. Average values of multiprobe parameters measured at the deepest point in each lake. For each lake, the profile was averaged, and then parameters were averaged to develop an average across the lakes. Orp = Oxidative Reduction potential. NTU = Nephelometric Turbidity Units

	Temperature (°C)	Specific Conductivity (μs/cm)	Dissolved oxygen (mg/L)	pH	Orp (mV)	Turbidity (NTU)
Mean	12.8	17.38	9.06	7.5	199	5.00
Range	8.4 - 18.0	0 - 96	7.3 - 11.9	6.2 - 9	53 - 564	3.6 - 9.7
Standard deviation	2.76	23.8	1.2	0.68	109.3	1.4
Coefficient of variation	21.6	136.9	13.7	9.1	54.8	28.7

Water chemistry

Successful water chemistry was collect at all 21 sites (Table 4). Where water chemistry samples were taken at two depths, the shallow sample was averaged with the deep sample. The highest variation was in sulfate, which was driven by a single site with high sulfate (probably geothermal in origin) in Forest Lake.

Table 4. Means and measures of dispersion for water chemistry parameters averaged across sites. All units are in mg/L.

Parameter	Mean	Standard Deviation	Coefficient of variation	Range
Total Nitrogen	0.359	0.184	51.1	0.045 - 0.795
Total Phosphorous	0.018	0.013	74.2	0.003 - 0.0435
Inorganic nitrogen	0.004	0.004	94.2	0 - 0.0145
Organic nitrogen	0.355	0.185	52.0	0.0415 - 0.7935
Ammonia	0.009	0.007	78.7	0.0005 - 0.025
Silicon	3.139	5.538	176.4	0.035 - 24.045
Sodium	1.170	1.650	141.1	0.07 - 6.8
Potassium	0.441	0.419	95.1	0.055 - 1.575
Calcium	3.862	11.443	296.3	0.125 - 52.97
Magnesium	0.929	1.244	133.9	0.035 - 5.29
Sulfate	3.467	14.156	408.3	0.01 - 58.4
Chloride	0.246	0.102	41.3	0.115 - 0.555
Organic carbon	4.309	2.273	52.7	0.355 - 10.925

Trophic state index

Trophic state indices calculated using nutrient data (total nitrogen and phosphorous) gave mostly comparable results (Table 5). Total nitrogen TSIs identified 12 oligotrophic lakes, 8 mesotrophic lakes, and 1 eutrophic lake. Total phosphorous TSIs identified 10 oligotrophic lakes, 6 mesotrophic lakes, and 5 eutrophic lakes. One lake, Forest Lake was identified as being oligotrophic using nitrogen, but eutrophic using phosphorous. The trophic state indices calculated for chlorophyll *a* biomass were problematic due to the use of inefficient filters caused low extracted values, resulting in negative values. For calculation and interpretation (e.g., variance and averages); any results using inefficient filters were disregarded. Trophic state indices based on Secchi depth were also problematic because so few lakes were deep enough so that clarity was obscured before the disk disappeared. However, where the disk was measureable, the TSIs were comparable to TSIs derived from both nitrogen and phosphorous.

Zooplankton

A total of 16,415 individual zooplankton specimens were identified from samples collected during the pilot project (Table 6). Of these, 14,295 were identified to the species level, 398 to the genus level, 49 to the family level, 311 to the subclass level, 1 to the class level, and 15 to the phylum level.

Sites had a high degree of variability in densities; from a low of 408 individuals per m^3 of water in Helen Lake, to a maximum of 617,437 individuals per m^3 in Unnamed Lake #34. Helen Lake also had the lowest diversity of zooplankton, with only 5 taxa collected. Inspiration Pond #2 had the highest diversity, with 31 taxa of zooplankton.

Table 5. Trophic state indices (TSI) for the lakes sampled for the pilot project. * indicates Chl *a* based TSI values with inefficient filters. Trophic state values (based on northern temperate lakes): <30 = Oligotrophic; 30 – 40 = Oligotrophic with possible anoxic region; 40 – 50 = Mesotrophic; 50 > Eutrophic. -- indicates Secchi disk was visible to the lake bottom, so unable to measure depth of disappearance. Average values, ranges, and standard deviation are based only on efficient Chlorophyll filters and Secchi depths with valid values.

| Site | Trophic state index | | | |
	Chl *a*	Total nitrogen	Total phosphorous	Secchi depth
Cluster Pond 4	0.4*	39.3	42.7	--
Summit Lake	-9.2*	41.6	42.7	--
Reflection Lake	-7.7*	51.1	57.7	51.5
Little Bear Lake	-12.7*	38.7	40.6	--
Cluster Lake 4	-33.0*	40.9	45.0	--
Cluster Lake 3	-25.6*	34.7	33.2	--
Helen Lake	-29.6*	10.2	20.0	--
Cliff Lake	-26.0*	31.2	56.8	--
Forest Lake	-9.3*	11.2	58.6	--
Unnamed #36	-4.1*	44.2	55.4	--
Unnamed #27	30.7	45.5	42.2	--
Jakey Pond #6	13.6	38.5	35.8	--
Inspiration Pond #2	18.6	46.3	49.4	--
Crystal Lake	26.5	30.9	31.1	--
Unnamed #34	34.2	47.1	57.3	--
Hidden Lake	31.3	38.0	39.4	--
Indian Lake	13.5	33.6	35.0	--
Indian Pond	20.3	37.5	37.4	37.9
Bathtub Pond	27.2	44.6	35.8	--
Rainbow Lake	14.0*	31.2	30.0	32.9
Soap Lake	-8.8*	42.3	37.4	--
Mean	24.0	37.1	42.1	40.8
Range	13.5 - 34.2	10.2 - 51.1	20 - 58.6	32.9 - 51.5
Standard deviation	7.7	10.4	10.5	9.6
Coefficient of variation	32.2	28.0	25.0	23.7

The "Chao 2" species estimator, applied to zooplankton data as it was to the macroinvertebrate data, suggests a total taxa richness of 183.6, whereas we only encountered 68 distinct taxa, so that only 37% of the potential species were sampled (Figure 2). Furthermore, the slope of the Chao 2 estimator suggests that no asymptote of taxa collection had been reached.

Table 6. Average zooplankton taxa richness, density, and Shannon index for lakes sampled during the Lake Pilot Project.

Site	Taxa Richness	Density per m^3	Shannon Index
Cluster Pond 4	13	3427	1.46
Summit Lake	19	8804	1.93
Reflection Lake	21	8330	1.18
Little Bear Lake	12	11920	1.76
Cluster Lake 4	10	26492	1.10
Cluster Lake 3	11	122282	1.10
Helen Lake	5	408	0.77
Cliff Lake	9	35020	0.65
Forest Lake	10	498	1.32
Unnamed #36	16	106774	1.30
Unnamed #27	23	3538	2.27
Jakey Pond #6	16	44274	1.16
Inspiration Pond 2	31	24613	1.61
Crystal Lake	11	41163	0.24
Unnamed #34	13	617437	0.36
Hidden Lake	11	56033	0.55
Indian Lake	11	14194	0.97
Indian Pond	14	99094	0.21
Bathtub Pond	15	32756	1.77
Rainbow Lake	12	15062	1.68
Soap Lake	9	5347	1.35
Mean	13.9	60832	1.18
Range	5 - 31	408 - 617437	0.21 - 2.27
Standard deviation	5.75	132450	0.57
Coefficient of Variation	41.4	217.7	48.4

Macroinvertebrates

A total of 12,507 individual macroinvertebrates specimens were enumerated and identified from all sites (Table 7). All taxonomic identifications were done by Rhithron, Inc. of Missoula, Montana. In all, 135 (1.1%) of all specimens were identified to the Order level, 1,791 (14.3%) were identified to the Family level, and 10,581 (84.6%) were identified to Genus/species level.

A total of 95 taxa were encountered at all taxa levels, including species not fully identified due to immature or damaged specimen. Counting unique taxa, a total of 90 were found. Of these, 25 were non-insect taxa (oligochaetes, water mites, and nematodes). The most dominant, both numerically and in species richness were Chironomidae (Diptera), the midges. Of other insect orders, only a single Megaloptera taxa (*Sialis* sp.) was encountered, 3 mayfly (Ephemeroptera), 4
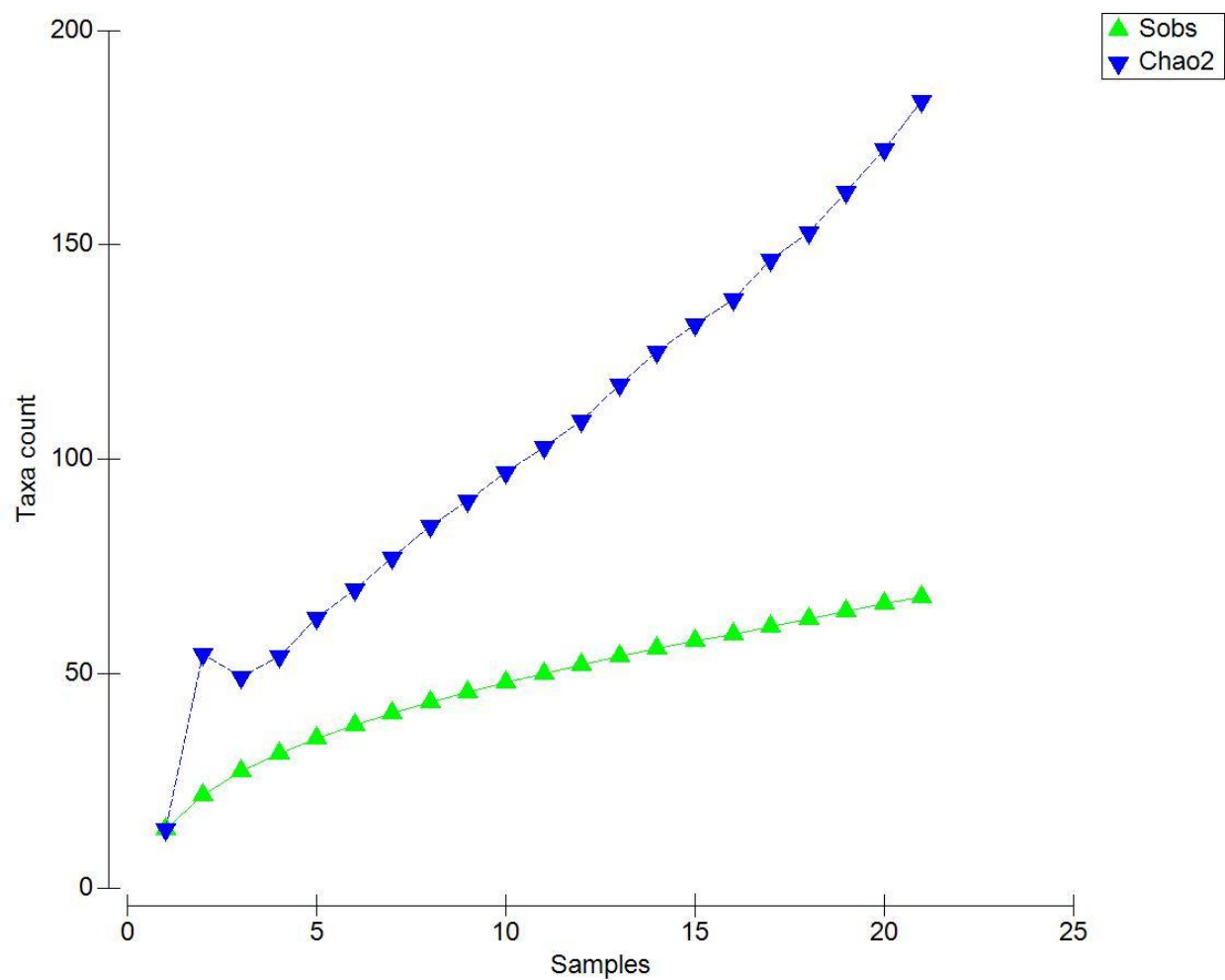
Figure 1. Species accumulation graphs for zooplankton sampling and species estimators using the "Chao2." Sobs = Species observed.

Table 7. Average macroinvertebrate taxa richness, density, Shannon Index, and Hilsenhoff Biotic Index for lakes sampled during Lake Pilot Project.

Site	Taxa Richness	Density per m^2	Shannon Index	Hilsenhoff Biotic Index
Cluster Pond 4	38	156.3	2.50	6.78
Summit Lake	34	563.4	2.71	6.87
Reflection Lake	41	738.8	2.36	7.13
Little Bear Lake	27	409.4	2.00	6.33
Cluster Lake 4	31	670.0	1.81	6.09
Cluster Lake 3	25	80.0	2.26	6.67
Helen Lake	18	3.0	2.62	6.85
Cliff Lake	16	425.3	0.71	6.27
Forest Lake	13	1655.5	0.84	6.19
Unnamed #36	19	2113.3	1.54	6.17
Unnamed #27	31	382.8	2.51	7.11
Jakey Pond #6	27	1151.3	2.12	6.50
Inspiration Pond 2	26	4712.7	2.09	6.02
Crystal Lake	32	322.0	2.51	6.46
Unnamed #34	25	302.9	2.20	7.10
Hidden Lake	34	97.4	2.83	6.08
Indian Lake	33	135.2	2.79	7.24
Indian Pond	34	742.0	2.79	6.93
Bathtub Pond	27	3215.0	1.50	7.57
Rainbow Lake	27	416.7	2.32	5.76
Soap Lake	31	124.4	2.38	6.12
Mean	28.0	877.0	2.16	6.58
Range	13 - 41	3 - 4712.7	0.71 - 2.83	5.76 - 7.57
Standard deviation	7.1	1177.4	0.59	0.49
Coefficient of Variation	25.5	134.3	27.47	7.42

true bugs (Heteroptera), 4 dragonfly and damselfly taxa (Odonata), and 14 beetles (Coleoptera) were encountered. A full taxa list is available in the Appendix.

The lake with the highest species richness was Reflection Lake, and the lowest species richness was in Forest Lake (Table 5). Density was very low in Helen Lake (3 per m^2); and extremely high in Inspiration Pond #2 (4,712.7 per m^2).

An overall high average Hilsenhoff Biotic Index of 6.58 was calculated. This value is high compared to stream values, and in this case is indicative of lentic ecosystems, and not of impairment.
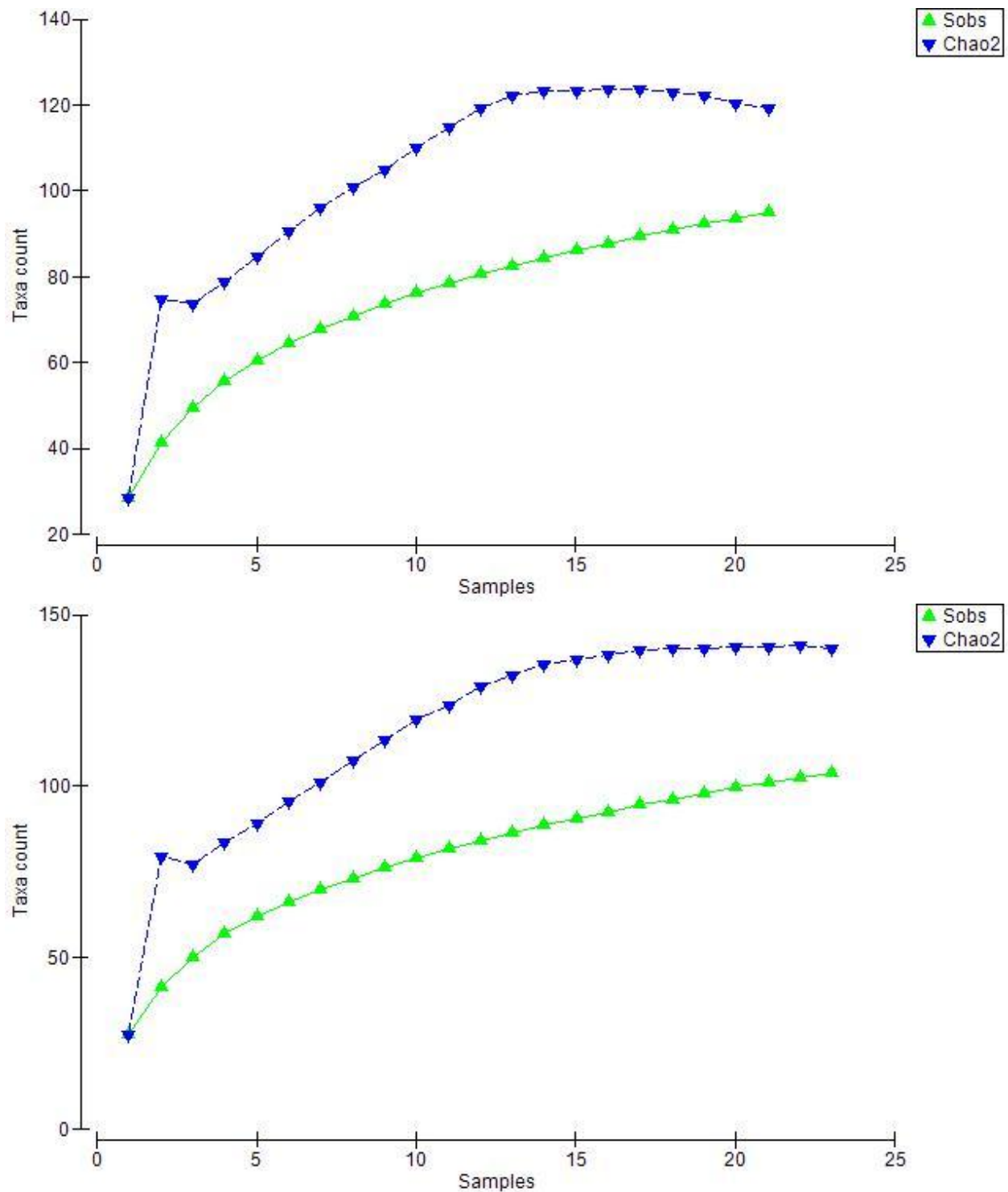
14

Figure 2. Species accumulation graphs for macroinvertebrate sampling and species estimators using the "Chao2." Top graph includes data only from quantitative sampling; bottom graph is use quantitative and qualitative sampling. Sobs = Species observed

15

The highest variation, measured using Coefficient of variation, was in the density estimates (134.3%) versus a very low variation in the Hilsenhoff Biotic Index (7.42%).

While we collected a total of 95 taxa from the quantitative sampling (using the total number of unique taxa regardless of resolution), we used species accumulation graphs coupled with species estimators ("Chao 2," Chao 1987) to assess the potential total macroinvertebrate taxa richness (Figure 3). The estimated total taxa richness was 119.3 from quantitative samples, so that we had collected 79.6% of the estimated taxa richness. When the qualitative sampling (done at Rainbow Lake and Soap Lake) was included, taxa not found in the other samples were added, for a total of 104 taxa, and an estimated total taxa richness of 140.3. In the qualitative sample, there were a total of 9 taxa that were not represented in any other lake quantitative sample: 5 beetles, 2 snails, 1 damselfly, and 1 mayfly.

Amphibians

A total of four amphibian species were encountered during the surveys. *Bufo boreas* (Western toads) were found at only Cliff Lake. *Pseudacris regilla*, the Pacific treefrog was the most widely distributed, found at Cliff Lake, Cluster Lakes 3 and 4, Summit Lake, and Reflection Lake. A single adult *Taricha granulosa,*(Rough-skinned newt) was observed at Cluster Pond 4. *Ambystoma macrodactylum* (Long-toed salamanders) were found at Cliff Lake, Bathtub Pond, Rainbow Lake. No individuals of the threaten Cascade Frog, *Rana cascade*, were seen during the surveys.

The long-toed salamanders (31 specimens total) at Cliff Lake were either moribund, sluggish individuals or were dead. All specimens encountered were metamorphs, metamorphosing from the larval stage to the adult stage. Specimens that were examined showed red petechia (1-2 mm diameter spots), symptomatic of microhemorraghes, as well as edemal swelling. Necroscopy of specimens sent to the USGS National Wildlife Health Center in Madison, WI confirmed a diagnosis of Ranavirus.

Fish

Fish were encountered at only 2 locations: Reflection and Summit Lakes. At Reflection Lake, a total of 23 individuals of non-native Notemigonus crysoleucas (Golden shiner) were caught. The average condition factor of these specimens was 1.71. At Summit Lake, 5 non-native Salvelinus fontinalis (Brook trout) were caught, with an average condition factor of 1.78.

Relationships of biota to measured parameters

Overall, macroinvertebrates were more strongly related to both measured environmental parameters and water chemistry parameters than zooplankton (Table 8). Zooplankton were significantly related to the environmental parameters (e.g., habitat size, substrates); but only were weakly correlated ($r = 0.283$).

Table 8. Relationships of biota (macroinvertebrates and zooplankton) to environmental and water chemistry parameters. Environmental parameters are %substrate types, lake area, shoreline development and maximum depth. Water chemistry parameters are anions, cations, nutrients, and dissolved organic carbon. r = Spearman correlation coefficient (0 = not relationship; 1 = perfect concordance). Significance (p) is determined by randomized matrix elements.

	Macroinvertebrates	Zooplankton
Environmental	$r = 0.573$ ($p = 0.001$)	$r = 0.283$ ($p = 0.044$)
Water chemistry	$r = 0.417$ ($p = 0.017$)	$r = 0.284$ ($p = 0.057$)

Discussion

The sampling procedures from the draft protocol proved doable, with only minor alterations. An example of this is the intial protocol called for gill netting every lake, whereas only a subset of lakes were able to be netted due to being too shallow. The protocols, as written for the final submission takes all the lessons learned into account.

Water chemisty (anions, cations, and nutrients) are taken at two depths, when the lake is deeper than 2 m deep. The reasoning for this is that a thermocline may exist, separating the upper warmer waters from the deeper, colder waters where different biological and chemical processes may change the water chemistry. However, in this study, only on lake our of 21 was found to have a thermocline. This suggests that for the majority of the lakes, one sample may be sufficient to characterize the lake in a broad sense. However, our sampling for the pilot project was done later in the year, after some thermoclines may have broken down due to wind-driven mixing of the waters. Therefore, we will continue to take shallow and deep water samples during the implementation of the project. In the future, if sampled lakes continue to not have thermoclines, an option may be to reduce the water sampling to one sample per lake.

Trophic state indices, based on nutrients, Secchi depths, and chlorophyll *a* gave similar results for most lakes. Secchi depth proved difficult to use park wide, because most lakes had clarity that exceeded their depth (i.e., the disk was visible to the bottom). However on the three lakes where it was usable, the TSI values were similar to the nutrient TSI values. Although limited usability might suggest dropping Secchi depths from the protocol, Secchi depths are widely measured across the nation as part of citizen science for monitoring lakes. Therefore, any contribution of the Klamath Network Lake program to the wider vision is beneficial.

One lake, Forest Lake, had conflicting values for the nutrient based TSIs (Nitrogen TSI = 11.2 [or oligotrophic]; Phosphorous TSI = 58.6 [or eutrophic]). Although other lakes had some variance around TSI values, with Chl *a* based ones being the lowest, nitrogen being middle, and phosphorous tending to be the highest, this discrepancy was the highest observed. Examination of the water chemistry values for the cations and anions showed that this lake was also extremely high in both sulfate (3 orders of magnitude higher than other sites) and silica, along with no acid neutralizing capability. In sum, Forest Lake is likely a lake highly influenced by volcanic activity, and would justify more study. This also shows the usefulness of secondary parameters, such as anions and cations, which give context and understanding to other attributes. Without these, a preliminary assessment might be that Forest Lake has a problem from a phosphorous stressor, such as sewage.

One problem encountered was the filter choice for the chlorophyll sampling. The draft protocols did not specify the filter type; and the wrong type membrane filter was procured. This has been fixed in the final protocol. Crews also found that the filters used were challenging to push the full aliquot of water through the filter, so that sometimes, multiple filters were used. The only other difficulty was that only 1 L of water per sample was retrieved per sample, with 250 ml for filtered water, 60 ml for dissolved organic carbon, 300 ml for chlorophyll *a*, and 300 ml for acid neutralizing capacity (250 + 60 + 300 + 300 = 910 total). Only 1000 ml with 910 ml available

was found to be too close for spillage or mistakes. Based on this a larger amount of water per sample will be retrieved in the final protocol.

The biological sampling was straight-forward throughout the pilot project. The results from both the zooplankton and macroinvertebrates showed the utility of tracking ecosystem changes in diversity (species richness and Shannon index) since both of these parameters had relatively low coefficients of variation, especially as opposed to density measurements. For the macroinvertebrates, a good portion of the potential total diversity (using the Chao 2 estimator) was sampled; whereas the zooplankton assemblage was not. However, monitoring the zooplankton still merits inclusion; based on (1) valuable information for describing total species richness in the park; (2) the development of indices based on zooplankton in the future; and (3) relatively high power to detect change (Power analyses in Dinger et al. 2009, this document).

The relationship of the macroinvertebrates to environmental and water chemistry parameters were high, especially compared to the zooplankton. This is valuable information, in that it shows that monitoring macroinvertebrate assemblages can reflect changes to their habitats and water quality. Although the zooplankton are not as strongly correlated with these other measurements, this might suggest that the zooplankton assemblage are representative of other ecosystem measurements, not captured in our monitoring. Hence, zooplankton are valuable in that they might reflect the change to those unseen and unmonitored ecosystem parameters.

The amphibian monitoring discovered an outbreak of an amphibian disease, ranavirus in the course of the pilot project. The strain of ranavirus infecting the long-toed salamanders has been shown to be one capable of infecting other species of amphibians, both frogs and salamanders. This justifies the suggestion that existing diseases may have played a role in the disappearance of the Cascade Frog in Lassen Volcanic National Park. Further study and research should be pursued to understand the full threat that ranavirus poses to the park biota.

Literature Cited

Carlson, R. E. 1977. A trophic state index for lakes. Limnology and Oceanography **22**:378-369.

Chao, A. 1987. Estimating the population size for capture-recapture data with unequal catchability. Biometrics **43**, 783-791.

Clarke, K.R. and R.M. Warwick. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. Primer-E: Plymouth, United Kingdom.

Dinger, E.C., Sarr, D.A., Mohren, S.R., and Hoffman, R.L. 2009. Integrated Aquatic community and Water Quality Monitoring of Mountain Ponds and Lakes in the Klamath Network. Natural Resource Report NPS/KLMN/NRTR—2009/XXX. National Park Service, Fort Collins, Colorado.

Sarr, D. A., D. C. Odion, S. R. Mohren, E. E. Perry, R. L. Hoffman, L. K. Bridy, and A. A. Merton. 2007. Klamath Network Vital Signs Monitoring Plan. Natural Resource Report NPS/KLMN/NRR—2007/016. National Park Service, Fort Collins, CO.

Wetzel, R. G. 2001. Limnology: Lake and River Ecosystems. 3rd edition. Elsevier Academic Press, San Diego, CA.

Appendix 1. Taxonomic results of organisms collected during Zooplankton tows and identified by contract laboratory. ITIS TSN = Integrated Taxonomic Information System (www.itis.gov) Taxonomic Serial Number, a unique serial number assigned to each taxon that provides updated taxonomy and status. [1] = this species is currently under revision; current accepted name is *H. arctius*, but other authors refer to *H. eiseni occidentalis*. [2] = *C. gibba* is closest fit to this taxa; contract laboratory expressed some question to the validity of this identification.

Phylum	Class	Order	Family	Genus	species	ITIS TSN
Annelida	Clitella (subclass Oligochaeta)					68422
Arthropoda	Arachnida	Trombidiformes				82769
Arthropoda	Branchiopoda	Diplostraca	Bosminidae	*Bosmina*	*longirostris*	83938
Arthropoda	Branchiopoda	Diplostraca	Chydoridae	*Acroperus*	*harpae*	84023
Arthropoda	Branchiopoda	Diplostraca	Chydoridae	*Alona*	*costata*	83983
Arthropoda	Branchiopoda	Diplostraca	Chydoridae	*Alona*	*guttata*	83975
Arthropoda	Branchiopoda	Diplostraca	Chydoridae	*Chydorus*	*sphaericus*	83993
Arthropoda	Branchiopoda	Diplostraca	Chydoridae	*Picripleuroxus*	*striatus*	684648
Arthropoda	Branchiopoda	Diplostraca	Chydoridae			83973
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Ceriodaphnia*	*dubia*	83912
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Ceriodaphnia*	*pulchella*	83908
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Ceriodaphnia*		83905
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*	*ambigua*	83888
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*	*middendorffiana*	83890
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*	*pulex*	83874
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*	*pulicaria*	83885
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*	*rosea*	83891
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Scapholeberis*	*armata*	83928
Arthropoda	Branchiopoda	Diplostraca	Holopediidae	*Holopedium*	*gibberum*	83957
Arthropoda	Branchiopoda	Diplostraca	Macrothricidae	*Streblocerus*	*serricaudatus*	84127
Arthropoda	Branchiopoda	Diplostraca	Sididae	*Diaphanosoma*	*brachyurum*	83838
Arthropoda	Branchiopoda	Diplostraca	Sididae	*Sida*	*crystallina*	83863
Arthropoda	Insecta	Diptera	Chaoboridae	*Chaoborus*		125904

Phylum	Class	Order	Family	Genus	species	ITIS TSN
Arthropoda	Insecta	Diptera	Chironomidae			127917
Arthropoda	Maxillopoda	Cyclopoida	Cyclopidae			88634
Arthropoda	Maxillopoda	Cyclopoida	Cyclopidae	*Macrocyclops*	*albidus*	88738
Arthropoda	Maxillopoda	Cyclopoida	Cyclopidae	*Microcyclops*	*varicans*	88758
Arthropoda	Maxillopoda	Calanoida	Diaptomidae	*Hesperodiaptomus*[1]	*eiseni occidentalis*	666938
Arthropoda	Maxillopoda	Calanoida	Diaptomidae		aka *arctius*	
Arthropoda	Maxillopoda	Calanoida	Diaptomidae	*Leptodiaptomus*	*novamexicanus*	572718
Arthropoda	Maxillopoda	Calanoida	Diaptomidae	*Leptodiaptomus*	*signicauda*	666963
Arthropoda	Maxillopoda	Calanoida	Diaptomidae	*Leptodiaptomus*	*tyrrelli*	666966
Arthropoda	Maxillopoda	Calanoida	Temoridae	*Epischura*	*nevadensis*	85857
Arthropoda	Maxillopoda	Calanoida				85258
Arthropoda	Maxillopoda (subclass Copepoda)					85257
Arthropoda	Ostracoda					84195
Nemata						563956
Protozoa	Lobosa	Arcellinida	Difflugiidae	*Difflugia*		43948
Rotifera	Eurotatoria	Bdelloida	Philodinidae	*Philodina*		58276
Rotifera	Eurotatoria	Bdelloida				58247
Rotifera	Eurotatoria	Flosculariaceae	Conochilidae	*Collotheca*	*mutabilis*	59435
Rotifera	Eurotatoria	Flosculariaceae	Conochilidae	*Conochilus*	*unicornis*	59419
Rotifera	Eurotatoria	Flosculariaceae	Filiniidae	*Filinia*	*terminalis*	59428
Rotifera	Eurotatoria	Ploima	Brachionidae	*Kellicottia*	*bostonensis*	58487
Rotifera	Eurotatoria	Ploima	Brachionidae	*Kellicottia*	*longispina*	58486
Rotifera	Eurotatoria	Ploima	Brachionidae	*Keratella*	*cochlearis*	58360
Rotifera	Eurotatoria	Ploima	Brachionidae	*Keratella*	*serrulata*	58384
Rotifera	Eurotatoria	Ploima	Brachionidae	*Keratella*	*taurocephala*	58381
Rotifera	Eurotatoria	Ploima	Gastropodidae	*Ascomorpha*	*saltans*	59168
Rotifera	Eurotatoria	Ploima	Gastropodidae	*Gastropus*	*stylifer*	59177

Phylum	Class	Order	Family	Genus	species	ITIS TSN
Rotifera	Eurotatoria	Ploima	Lecanidae	*Lecane*	*tenuiseta*	58711
Rotifera	Eurotatoria	Ploima	Lecanidae	*Lecane*		58634
Rotifera	Eurotatoria	Ploima	Lecanidae	*Monostyla*	*bulla*	58748
Rotifera	Eurotatoria	Ploima	Lecanidae	*Monostyla*	*cornuta*	58756
Rotifera	Eurotatoria	Ploima	Lecanidae	*Monostyla*	*lunaris*	58753
Rotifera	Eurotatoria	Ploima	Lepadellidae	*Lepadella*	*ovalis*	58491
Rotifera	Eurotatoria	Ploima	Notommatidae	*Cephalodella*	*gibba (?)*[2]	58821
Rotifera	Eurotatoria	Ploima	Synchaetidae	*Ploesoma*	*hudsoni*	59291
Rotifera	Eurotatoria	Ploima	Synchaetidae	*Ploesoma*	*truncatum*	59283
Rotifera	Eurotatoria	Ploima	Synchaetidae	*Polyarthra*	*dolichoptera*	59273
Rotifera	Eurotatoria	Ploima	Synchaetidae	*Polyarthra*	*major*	59275
Rotifera	Eurotatoria	Ploima	Synchaetidae	*Polyarthra*	*remata*	59276
Rotifera	Eurotatoria	Ploima	Synchaetidae	*Polyarthra*	*vulgaris*	59277
Rotifera	Eurotatoria	Ploima	Synchaetidae	*Synchaeta*		59255
Rotifera	Eurotatoria	Ploima	Trichoceridae	*Trichocerca*	*multicrinis*	59078
Rotifera	Eurotatoria	Ploima	Trichoceridae	*Trichocerca*	*similis*	59079
Rotifera	Eurotatoria	Ploima	Trichotriidae	*Trichotria*	*tetractis*	58565
Tardigrada						155166

Appendix 2. Taxonomic results of organisms collected during Invertebrate sweeps and identified by contract laboratory. ITIS TSN = Integrated Taxonomic Information System (www.itis.gov) Taxonomic Serial Number, a unique serial number assigned to each taxon that provides updated taxonomy and status. 1 = Identification of the group of species is impossible in early instars – genera in this group are: *Arctopelopia*, *Conchapelopia*, *Hayesomyia*, *Heloelopia*, *Meropelopia*, *Rheoelopia*, *Telopelopia*, and *Thienemannimyia*.

Phylum	Class	Order	Family	Genus	species	ITIS TSN
Annelida	Clitellata	Arhynchobdellida	Erpobdellidae	*Mooreobdella*		69449
Annelida	Clitellata	Arhynchobdellida	Haemopidae	*Haemopis*		69408
Annelida	Clitellata	Haplotaxida	Enchytraeidae	*Enchytraeus*		68531
Annelida	Clitellata	Haplotaxida	Enchytraeidae	*Mesenchytraeus*		68544
Annelida	Clitellata	Haplotaxida	Naididae	*Dero*		68898
Annelida	Clitellata	Haplotaxida	Naididae	*Nais*		68946
Annelida	Clitellata	Haplotaxida	Naididae	*Vejdovskyella*		69009
Annelida	Clitellata	Haplotaxida	Naididae			68854
Annelida	Clitellata	Haplotaxida	Tubificidae	*Aulodrilus*		68679
Annelida	Clitellata	Lumbriculida	Lumbriculidae	*Lumbriculus*		68441
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	*Glossiphonia*		69380
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	*Helobdella*	*stagnalis*	69398
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae			69357
Arthropoda	Arachnida	Trombidiformes	Arrunuridae	*Arrenurus*		82864
Arthropoda	Arachnida	Trombidiformes	Hydrodromidae	*Hydrodroma*		83225
Arthropoda	Arachnida	Trombidiformes	Lerbertiidae	*Lebertia*		83034
Arthropoda	Arachnida	Trombidiformes	Pionidae	*Piona*		83350
Arthropoda	Arachnida (subclass Acari)					733321
Arthropoda	Cladocera					83678
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Acilius*	*abbreviatus*	112080
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Agabus*		111966
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Coptotomus*	*longulus*	112373
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Dytiscus*	*dauricus*	112135
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Hygrotus*		112200

Phylum	Class	Order	Family	Genus	species	ITIS TSN
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Liodessus*		112580
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Oreodytes*	*humboldtensis*	728441
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Rhantus*	*wallisi*	112092
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Sanfilippodytes*		728253
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Stictotarsus*		568826
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Stictotarsus*	*griseostriatus*	728483
Arthropoda	Insecta	Coleoptera	Dytiscidae			111963
Arthropoda	Insecta	Coleoptera	Elmidae	*Optioservus*		114177
Arthropoda	Insecta	Coleoptera	Gyrinidae	*Gyrinus*	*plicifer*	112672
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	*obscurus*	112965
Arthropoda	Insecta	Diptera	Ceratopogonidae (subfamily Ceratopogoninae)			127338
Arthropoda	Insecta	Diptera	Chaoboridae			125886
Arthropoda	Insecta	Diptera	Chironomidae	*Ablabesmyia*		128079
Arthropoda	Insecta	Diptera	Chironomidae	*Apedilum*		206655
Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*		129254
Arthropoda	Insecta	Diptera	Chironomidae	*Cladopelma*		129350
Arthropoda	Insecta	Diptera	Chironomidae	*Cladotanytarsus*		129873
Arthropoda	Insecta	Diptera	Chironomidae	*Clinotanypus*		127996
Arthropoda	Insecta	Diptera	Chironomidae	*Corynoneura*		128563
Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*		128575
Arthropoda	Insecta	Diptera	Chironomidae	*Cryptochironomus*		129368
Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes*		129428
Arthropoda	Insecta	Diptera	Chironomidae	*Guttipelopia*		128161
Arthropoda	Insecta	Diptera	Chironomidae	*Heterotrissocladius*		128737
Arthropoda	Insecta	Diptera	Chironomidae	*Limnophyes*		128776
Arthropoda	Insecta	Diptera	Chironomidae	*Microtendipes*		129535
Arthropoda	Insecta	Diptera	Chironomidae	*Nilothauma*		129548

Phylum	Class	Order	Family	Genus	species	ITIS TSN
Arthropoda	Insecta	Diptera	Chironomidae	*Pagastiella*		129561
Arthropoda	Insecta	Diptera	Chironomidae	*Parakiefferiella*		128968
Arthropoda	Insecta	Diptera	Chironomidae	*Paramerina*		128207
Arthropoda	Insecta	Diptera	Chironomidae	*Paratanytarsus*		129935
Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*		129657
Arthropoda	Insecta	Diptera	Chironomidae	*Procladius*		128277
Arthropoda	Insecta	Diptera	Chironomidae	*Psectrocladius*		129018
Arthropoda	Insecta	Diptera	Chironomidae	*Psectrotanypus*		128048
Arthropoda	Insecta	Diptera	Chironomidae	*Pseudochironomus*		129851
Arthropoda	Insecta	Diptera	Chironomidae	*Tanytarsus*		129978
Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia* Group[1]		NA
Arthropoda	Insecta	Diptera	Chironomidae	Tribe Tanytarsini		129872
Arthropoda	Insecta	Diptera	Chironomidae	*Tribelos*		129820
Arthropoda	Insecta	Diptera	Chironomidae	*Zavrelimyia*		128259
Arthropoda	Insecta	Diptera	Chironomidae (subfamily Orthocladiinae)			128457
Arthropoda	Insecta	Diptera	Chironomidae (subfamily Tanypodinae)			127994
Arthropoda	Insecta	Diptera	Tabanidae			130934
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Callibaetis*		100903
Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*		101478
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*		101187
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae			101095
Arthropoda	Insecta	Hemiptera	Belostomatidae	*Lethocerus*		103699
Arthropoda	Insecta	Hemiptera	Corixidae	*Cenocorixa*		103501
Arthropoda	Insecta	Hemiptera	Corixidae	*Sigara*		103369
Arthropoda	Insecta	Hemiptera	Corixidae			103364
Arthropoda	Insecta	Hemiptera	Notonectidae	*Notonecta*		103558
Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*		115002

Phylum	Class	Order	Family	Genus	species	ITIS TSN
Arthropoda	Insecta	Odonata	Aeshnidae	*Aeshna*		101603
Arthropoda	Insecta	Odonata	Aeshnidae	*Aeshna*	*walkeri*	592682
Arthropoda	Insecta	Odonata	Coenagrionidae	*Enallagma*		102102
Arthropoda	Insecta	Odonata	Coenagrionidae			102077
Arthropoda	Insecta	Odonata	Corduliidae	*Somatochlora*		101947
Arthropoda	Insecta	Odonata	Corduliidae	*Somatochlora*	*albicincta*	101952
Arthropoda	Insecta	Odonata	Libellulidae	*Leucorrhinia*	*glacialis*	101886
Arthropoda	Insecta	Odonata	Libellulidae			101797
Arthropoda	Insecta	Trichoptera	Calamoceratidae	*Heteroplectron*	*californicum*	116538
Arthropoda	Insecta	Trichoptera	Lepidostomatidae	*Lepidostoma*		116794
Arthropoda	Insecta	Trichoptera	Leptoceridae	*Mystacides*		116598
Arthropoda	Insecta	Trichoptera	Leptoceridae	*Oecetis*		116607
Arthropoda	Insecta	Trichoptera	Leptoceridae			116547
Arthropoda	Insecta	Trichoptera	Limnephilidae	*Hesperophylax*		116001
Arthropoda	Insecta	Trichoptera	Limnephilidae			115933
Arthropoda	Insecta	Trichoptera	Phryganeidae	*Banksiola*		115911
Arthropoda	Insecta	Trichoptera	Phryganeidae			115867
Arthropoda	Insecta	Trichoptera	Polycentropidae	*Polycentropus*		117044
Arthropoda	Insecta	Trichoptera	Sericostomatidae	*Gumaga*		117003
Arthropoda	Malacostraca	Amphipoda	Hyalellidae	*Hyalella*		94025
Arthropoda	Maxillopoda (subclass copepoda)					85257
Arthropoda	Ostracoda					84195
Mollusca	Bivalvia	Veneroida	Pisidiidae			81388
Mollusca	Gastropoda	Basommatophora	Ancylidae	*Ferrissia*		76569
Mollusca	Gastropoda	Basommatophora	Planorbidae	*Gyraulus*		76592
Mollusca	Gastropoda	Basommatophora	Planorbidae	*Planorbella*	*trivolvis*	76671
Mollusca	Gastropoda	Heterostropha	Valvatidae	*Valvata*		70346

Phylum	Class	Order	Family	Genus	species	ITIS TSN
Nemata						563956

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National Park Service
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